Chapter 2
Overview of Wind Development and Permitting

INTRODUCTION

This chapter describes the basic features of a wind project and the steps developers take to get a project on line. It also provides some background information on the wind energy industry, a brief history of commercial wind development in the United States, wind power's potential for meeting our electricity needs, and the extent to which it has expanded internationally.

In the United States, commercial wind development began in California in the early 1980s, producing the world's first large-scale wind plants. California's wind plants or "wind facilities" have been installed primarily in three wind resource areas: the Altamont Pass located east of San Francisco, the Tehachapi Pass located north of Los Angeles and east of Bakersfield, and the San Gorgonio Pass located east of Los Angeles and northwest of Palm Springs. Together these represent about 95% of California's wind-generated electricity. Development proceeded rapidly during the first half of the 1980s as wind developers took advantage of federal and state tax credits and long-term utility contracts offering favorable rates. These economic incentives helped California's wind industry to grow from no installed capacity in 1979 to about 500 megawatts[1] (MW) at the beginning of 1985, to a high of 1,679 MW at the end of 1991. In 1994, the state's wind industry generated a record high of 3.2 billion kilowatt-hours[2] (kWh) of electricity, enough output to meet the annual electricity needs of more than 500,000 typical California homes (Loyola, 1995).

Wind development in California has slowed considerably in recent years. From 1992 to 1994, only 79 MW of new capacity was installed. This slowdown was the result of several factors, including limited financial incentives (federal and state tax credits expired in 1985 and 1986, respectively), the expiration of the fixed payment phase of the Interim Standard Offer (ISO4) utility contracts, and the electricity industry's uncertainty about restructuring. Over the same period, many older turbines were retired after reaching the end of their economical service life (CEC, 1997). In this economic environment, California's installed capacity dropped to 1,523 MW at the end of 1995. Electricity production also had declined to 2.9 billion kWh (Small, 1997).

In some cases, wind plant owners have chosen to replace older turbines with modern technology, a process known as "repowering." Modern wind turbines are quieter, more reliable, and, being larger, are sited less densely. (For example, one California wind plant operator replaced 85 old turbines with seven new 600 kW machines.) Thus repowering has the advantages of increasing electricity production while lowering operation and maintenance costs and alleviating public concern, particularly with regard to noise and visual impacts (AWEA, 1993). Repowering has the added benefit of utilizing existing sites with known wind resources, thereby reducing the costs and siting issues associated with development of new resources (CEC, 1997). As California's wind plants are repowered, salvageable turbines may have value as an inexpensive source of turbines for new projects elsewhere in the US or the world (Gipe, 1995).

While California continues to dominate wind-generated electricity production in the US, other states also are using their wind resources. These include Minnesota, Iowa, Texas, Vermont, Massachusetts, Hawaii, and Wyoming. According to the American Wind Energy Association (AWEA), the US had 1,770 MW of installed wind capacity at the end of 1995 (AWEA, 1996a). A study of US wind resource potential by the Pacific Northwest Laboratory found that wind power could supply 20% of the nation's electricity needs. To produce this electricity—nearly 560 billion kWh annually—would require development of 18,000 square miles of land, or 0.6% of the land area of the lower 48 states. Less than 5% of this land would be occupied by the wind turbines, electrical equipment, and access roads. Wind development would not prevent the use of the remaining land area for other purposes, such as farming and ranching (UWIG, 1992). The relationship of a wind project's "footprint" to other land uses is discussed further in Chapter 4.

While the US market for wind energy has leveled off in recent years (in part because of the electricity industry's uncertainty over restructuring), the wind power industry is experiencing rapid growth on the international front. In 1995, world installed capacity increased by 1,291 MW, two-thirds of which occurred in Germany and India alone. In this same year, the US installed only 41 MW of new capacity (AWEA, 1996b). New installations worldwide in

[1]A megawatt is one million watts.
[2]A kilowatt (kW) is one thousand watts. A kilowatt-hour (kWh) is one kilowatt of electricity supplied for one hour.

1996 amounted to 1,225 MW, with Germany and India again leading the way, adding 439 MW and 264 MW respectively (AWEA, 1997). As a result of increased development abroad, combined with the slow rate of domestic growth and retirement of California's older turbines, the US has seen its share of total world wind capacity drop from about 90% to 30% since 1988 (AWEA, 1996b). AWEA states that much of the wind industry's growth in other countries can be attributed to government policies designed to foster the use of clean, renewable energy sources. Countries that have been developing their wind resources include: Denmark, the Netherlands, the United Kingdom, Spain, Sweden, Greece, New Zealand, Australia, China, Costa Rica, Brazil, Israel, Iran, and Italy.

Wind energy and other renewable energy sources, such as solar and geothermal energy, offer the prospect of producing an increasing share of US electricity production with greatly reduced effects on the environment. The recoverable portion of the total wind resource in the contiguous US is approximately 110 quads—about four times the 48 states' total electricity consumption in 1990 (Pacific Northwest Laboratory, 1991). While technical and other issues will limit the contribution of wind energy, its potential is quite large.

ANATOMY OF A WIND PROJECT

Wind projects vary greatly in size, from one or two wind turbines ("distributed wind systems") serving individual customers or operating either at substations or at the end of a utility's distribution system, to large arrays of wind turbines ("wind facilities") designed for providing wholesale bulk electricity to utilities or an electricity market.

Distributed wind systems. Most distributed wind systems range in size from one kW to 25 MW, providing on-site power in either stand-alone or grid-connected configurations. Such systems are used by industry, water districts, schools, rural residences, farms, and other remote power users. Distributed wind systems also can be used by utilities for reducing loads at the end of heavily used power lines. By installing turbines close to the point of demand, utilities can avoid the costs of upgrading their electrical distribution systems (Gipe, 1995).

Wind facilities. Larger arrays usually are owned and operated by independent power producers which traditionally have sold their power to electric utilities. Wind facilities vary in generating capacity anywhere from five to more than 100 MW and may consist of 20 to 1,000 wind turbines of the same or different models. The turbines may be mounted on towers of equal or varying height and often are placed in linear arrays along ridgetops or sited in uniform patterns on flat or hilly terrain (see Figures 1, 2, and 3).

The wind turbine on its tower is the most noticeable feature of a wind project. Other components may include anemometers (wind measuring equipment), an electrical power collection and transmission system (transformers, substation, underground and/or overhead lines), control and maintenance facilities, and site access and service roads (see Figure 4). All of these components may not be included in smaller projects. Each component is described in the paragraphs that follow.

Wind Turbines

Wind turbines capture the kinetic energy of the wind and convert it into electricity. The primary components of a wind turbine are the rotor (blade assembly), electrical generator, and tower. As the wind blows it spins the wind turbine's rotor, which turns the generator to produce electricity. Figures 5 and 6 illustrate some typical turbine designs.

The rotor is the part that captures the wind. On most wind turbines the rotor consists of two or three blades which spin about a horizontal axis. "Upwind" turbines have the blades facing into the wind, in front of the generator and tower. The blades on "downwind" turbines are located behind the generator and tower. Less common are the Darrieus (or "eggbeater") wind turbines, whose rotors spin about a vertical axis.

The nacelle, mounted on top of the tower, houses the wind turbine's electrical generator. A generator's rating, in kilowatts or megawatts, indicates its potential power output. Actual generation, as kilowatt- or megawatt-hours, will depend on rotor size and wind speed. Larger rotors allow turbines to intercept more wind, increasing power output. The amount of power in the wind is a cubic function of wind speed; thus wind turbines produce an exponentially increasing amount of power as wind speeds increase. For example, if the wind speed doubles, wind power increases eight-fold.

A wind turbine's blades typically begin spinning as wind speeds reach approximately seven miles per hour (mph). At nine to 10 mph ("cut-in" speed),

Figure 1. Rows of wind turbines in the Altamont Pass, sited to take advantage of strong summer winds. Photo courtesy of the American Wind Energy Association (AWEA).

they will start generating electricity. Rated output is usually reached in 27 to 35 mph winds. To avoid damage, most turbines automatically shut themselves down when wind speeds exceed 55 to 65 mph (“cut-out” speed). Because wind is intermittent, wind turbines will seldom operate at their rated power output for long periods of time.

Wind turbines are mounted on lattice (open framework) or tubular steel towers. The tower’s function is to raise the wind turbine high enough above the ground to intercept stronger winds that provide more energy. Taller towers also usually allow turbines to capture less turbulent winds, unimpeded by nearby trees, buildings, and other obstructions. Tubular towers are anchored to concrete foundations 15 to 35 feet deep to prevent them from being toppled by strong winds. Lattice towers use three or four piers instead of a single massive concrete pad.

As the industry has gained experience, rotor diameter, generator rating, and tower height have all increased. During the early 1980s, wind developers were installing turbines with rotor spans of 10 to 15 meters (about 33 to 49 feet) and generators rated at 10 to 65 kW. By the mid- to late 1980s, turbines began appearing with rotor diameters of 15 to 25 meters (m) and generators rated up to 200 kW (Gipe, 1995; AWEA, 1993). Today, wind developers are installing turbines rated at 225 to 750 kW with rotor spans of 25 to 44 m. According to the California Energy Commission, 99% of all new capacity installed in California during 1994 was larger than 200 kW (Loyola, 1995). In part to accommodate larger rotors, tower height has increased from 18 m common during the early 1980s to 30 to 49 m for today’s turbines.

According to AWEA, today’s large wind turbines produce as much as 10 times the amount of electricity as early designs with about the same operation and maintenance (O&M) costs, thus dramatically cutting O&M costs per kWh. Improvements in turbine technology and maintenance programs have produced highly reliable, efficient machines. According to AWEA, the turbines used in the early 1980s were available for operation 60% of the time. Today’s state-of-the-art wind turbines have an availability rating of 98% (AWEA, 1993; AWEA, 1995).

Figure 2. Open lattice wind towers in the Altamont Pass. Note the service road in the foreground. Photo courtesy of AWEA.

Anemometers

Anemometers continuously measure and record wind speed. Anemometer towers usually are the first structures built on a site to determine if it has adequate wind resources for cost-effective development. Site-specific measurements (called "micro siting") identify the optimal placement for individual wind turbines. During operation of a wind facility, anemometers transmit information about wind speed and direction to each wind turbine and the control facility, where a record of wind speeds throughout the wind facility is stored. Anemometers can be mounted on towers as high as 350 feet or directly mounted on each wind turbine. Wind turbines will begin operating when the anemometers detect sufficient wind speed.

Power Collection and Transmission System

Large arrays of wind turbines require an extensive power collection and electric interconnection system for delivering electricity to the high voltage transmission system. Power generated by each wind turbine is typically carried by low voltage underground cables at 480 volts[3] to pad-mounted transformers located throughout the wind facility. There may be one transformer adjacent to each wind turbine or one for each row of turbines. The transformers raise ("step-up") the voltage to 12 to 34.5 kilovolts (1000 volts). Medium voltage underground cables collect the electricity from the transformers and deliver it to an overhead or underground collection line. Power is transmitted by the collection line to the wind facility's substation for further step-up, usually up to 69 to 230 kilovolts, before interconnection with and export to the high voltage transmission system.

[3]A unit of electromotive force.

Control Facility

An operations control facility maintains two-way communications with each wind turbine. This allows a central computer system to monitor and control each turbine's operation. The control facility can be located on- or off-site. Through the use of integrated computer systems, it is possible for a control facility in one location to monitor and control wind projects in several different locations.

Maintenance Facility

A large wind project will require a maintenance facility for storing trucks, service equipment, spare parts, lubricants, and other supplies. The maintenance facility may be located on- or off-site. Some wind facilities combine control and maintenance functions in one building.

Access Roads

There usually will be one or more access roads into and around a wind project. These service roads provide access to each wind turbine, and typically run parallel to a string of turbines. Some projects do not use permanent access roads. (See Chapter 4, *VISUAL RESOURCES*, for a discussion of alternatives to permanent roads.)

STEPS AND PARTICIPANTS IN WIND PROJECT DEVELOPMENT

Developing an operational wind project is a complicated and time-consuming process involving developers, landowners, utilities, the public, and various local, state, and federal agencies. Over 30 months is typically required from initial planning to project operation in an area without existing wind projects. The development time for subsequent projects at the same or a nearby site may be reduced by several months, provided that:

- permits are issued for the project as a whole and construction is done in phases;

- an Environmental Impact Statement (EIS) is done (in compliance with the National Environmental Policy Act or a state equivalent) for the first project and the results show that a subsequent EIS does not need to be prepared for later projects; and/or

- additional experience and knowledge about wind energy projects removes some of the uncertainties that contribute to lengthy analyses and processes.

The major steps in the wind project development process are described below.

- Project planning

- Permitting

- Financing

- Construction

- Operation

- Decommissioning

Planning

A wind project may be proposed by an independent company, a local government agency, or a unit of a traditional electric utility. The first step in developing a wind project is to identify a suitable site for the turbine or turbines and a likely market for the project's output. To identify possible wind development areas, developers usually consult published wind studies or wind resource maps such as Pacific Northwest Laboratory's *Wind Energy Resource Atlas of the United States* (listed in Appendix A). The developer will also study maps of the electric power system and the local area. To select a specific site within a region, developers may gather long-term wind information from the nearest wind measurement station. They will visit likely project site locations to collect general information, including obvious signs of strong winds (e.g. flagged trees, sand dunes and scours), the accessibility of the terrain, proximity to a utility transmission line, and any potential environmental constraints (see Chapter 4 for further discussion).

After finding a potentially suitable site, the developer negotiates to gain access to or control of the properties to conduct further investigations.

Figure 3. Tubular towers in a linear array in South Point, Hawaii. Photo by Paul Gipe.

Developers may secure options for long-term leases or simple anemometer agreements from the landowners. During the option period the developer obtains the landowner's permission to erect anemometers for making site-specific wind measurements. The developer usually collects data at the property for at least one full year to determine the average annual wind speed. More than one year may be needed if site measurements do not correlate well with those made by the closest wind measurement station. If wind data show that the site has economic potential for wind energy generation, the developer will prepare an initial site plan which proposes where to put the wind turbines and electrical facilities that connect to the power grid. Depending on market prospects, an anemometer

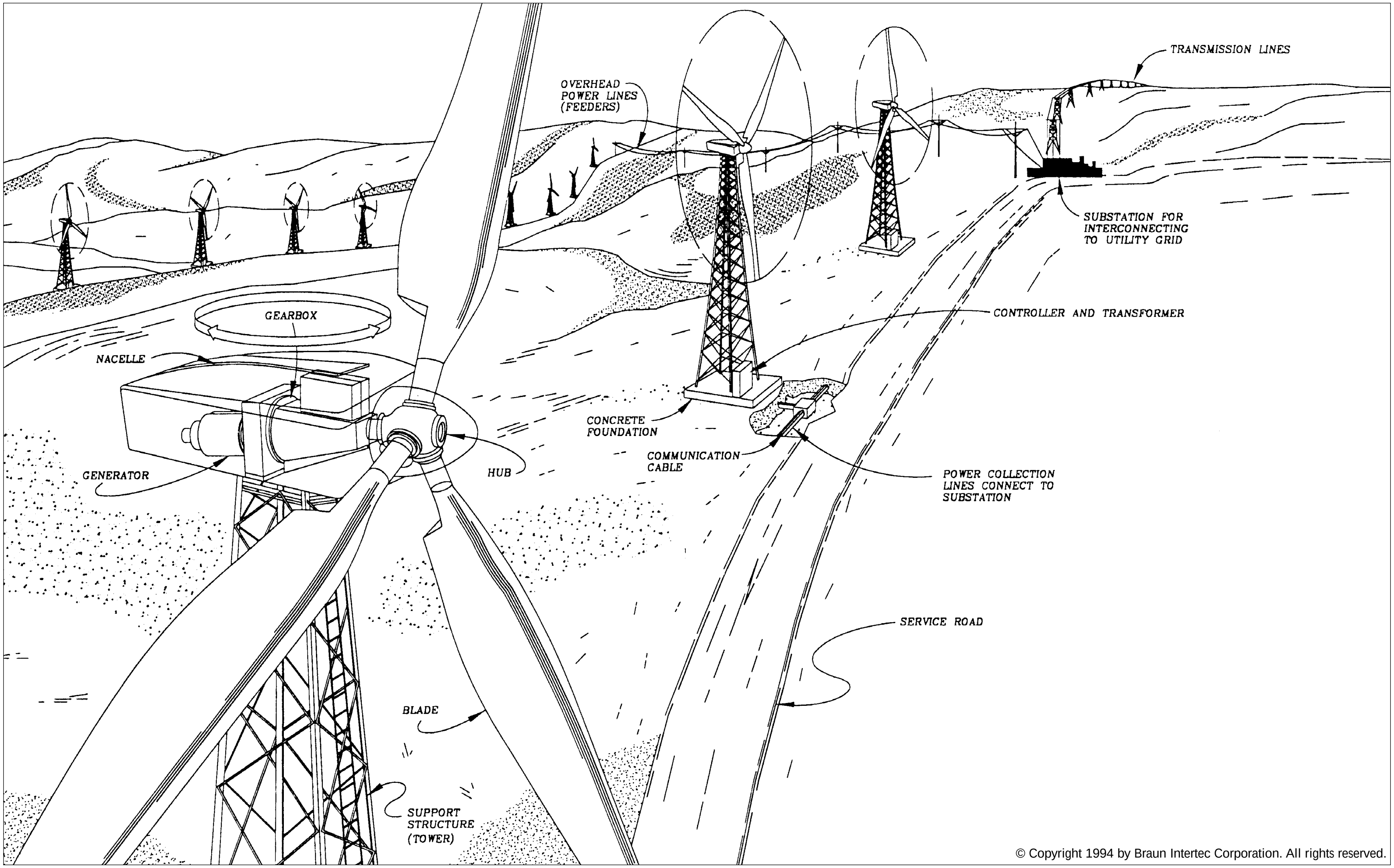

Figure 4. Typical wind farm facility layout.

Figure 5. A large 500-kW, three-bladed wind turbine towers 40 meters over a service vehicle. Photo courtesy of AWEA and Vestas-American Wind Technology.

agreement may be upgraded to an option or lease at this point.

Wind facility developers also begin negotiating with a utility or other buyer for a power purchase agreement, a transmission interconnection agreement, or both. At present, the likely purchaser of the electricity is the utility serving the area where the wind facility is located. In a restructured electricity industry, however, power may be sold to a more distant utility or to a different wholesale or retail customer. In this case, the developer will have to work with the local utility to obtain access to the existing transmission system.

While negotiating with a buyer, the developer will obtain exclusive long-term development rights to the property by either buying or leasing it from the landowner. If the land is leased, the landowner can negotiate with the developer the terms of the relationship between the wind facilities and other uses of the property, the location and type of access roads and other support facilities, and the condition of the land after wind operations cease. Lease conditions may influence some of the permitting considerations discussed in Chapter 4. The developer may also acquire easements from adjacent landowners to assure continuing access to the wind. Easements may restrict vegetation, structures, or other obstacles that would alter the flow of wind to the project site. Easements or leases may also be needed for the right to cross adjacent properties for the construction and maintenance of access roads or transmission lines.

Permitting

Virtually all wind projects are required to obtain a permit from one or more government agencies. Early in the project planning and development process, the wind developer should contact all potential permitting agencies or authorities. Permitting entities at the federal, state, and local levels may have jurisdiction over a wind development. The number of agencies and the level of government involvement will depend on a number of factors particular to each development. These factors primarily include: location of the wind turbines and associated facilities or equipment, need for transmission lines and access roads, the size of the wind facility, ownership of the project, and ownership of the land. Chapters 3 and 4 discuss the permitting process and various considerations for agencies that may be involved in permitting wind facilities.

Local permitting authorities. In many states the primary permitting jurisdiction for wind facilities is the local planning commission, zoning board, city council, or county board of supervisors or commissioners. Typically, these local jurisdictional entities regulate through zoning ordinances. In addition to local zoning approval, permitting under local jurisdiction may require a developer to obtain some form of local grading or building permit to assure compliance with structural, mechanical, and electrical codes.

State permitting authorities. In some states, one or more state agencies have siting responsibilities for wind developments. State permitting authorities may include natural resource and environmental protection agencies, state historic preservation offices, industrial development and regulation agencies, public utility commissions, or siting boards. Depending on the state where the wind development is proposed, state permits may be in addition to local permits. In other states, state law may supersede some or all local permitting authorities. Where there is state level regulation there may be either a coordinating or lead agency regulatory scheme or a "one-stop" siting process housed under one agency.

Whether the permitting jurisdiction is state or local, wind projects may be subject to local and state environmental policy acts. These laws generally adhere closely to the language of the National Environmental Policy Act (see below). The content requirements of these laws parallel those of federal law, except where specific language narrows the scope of the impact statements.

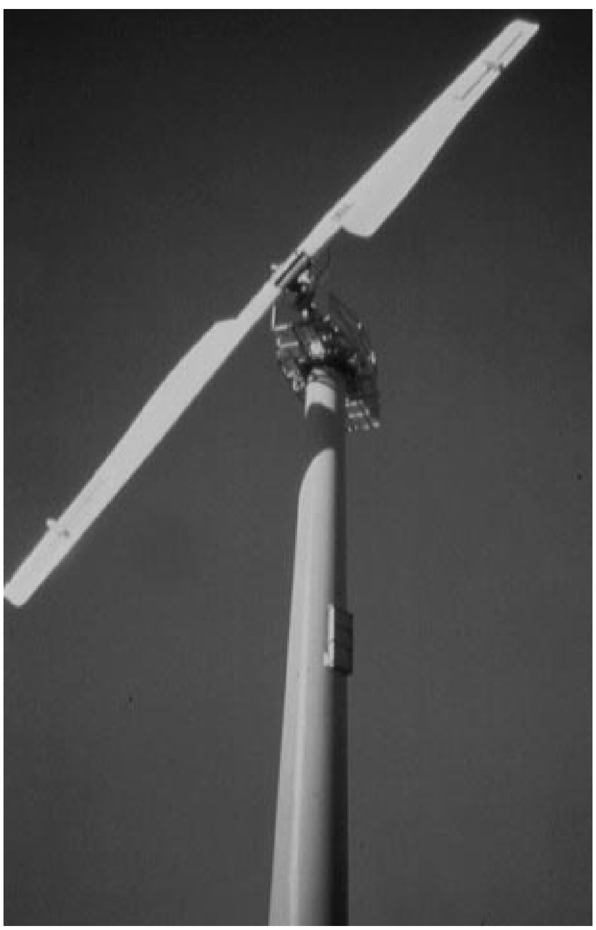

Figure 6. A two-bladed wind turbine design. Photo courtesy of AWEA.

Federal permitting authorities. In some cases (notably in the West), federal land management agencies such as the Bureau of Land Management or the United States Forest Service may be both the manager and the permitting authority. Additionally, agencies such as the Bonneville Power Administration or Western Area Power Administration may be either a wind developer or the customer for the power. If the proposed wind development facility has the potential to impact aviation, the Federal Aviation Administration may be involved. If the project poses potential impacts on wildlife habitat and species protected under the Endangered Species Act, the Bald and Golden Eagle Protection Act, or the Migratory Bird Treaty Act, wind project permitting may involve coordination and consultation with the United States Fish and Wildlife Service.

When federal agencies or federally managed lands and resources are involved, the requirements of the National Environmental Policy Act (NEPA) may apply. Compliance with NEPA will be required if the wind development or authorization to develop is a federal action, qualifies as "major," and has potential for a significant environmental impact. If a wind project is proposed on federal land, a federal agency has the power to control the authorization of the wind project (e.g., a federal permit or lease is required). In this case, or if there is a substantial commitment of federal resources (monetary or otherwise), there must be compliance with NEPA. Where multiple federal agencies have NEPA responsibilities, a lead agency will be appointed to coordinate NEPA compliance.

Involving the general public. Compliance with local, state or federal permitting processes involves the general public at some stage. Consequently, the wind developer can help assure a timely permit decision and reduce the possibility of protracted litigation by actively promoting general public involvement early in the permitting process. The general public includes residents and members of communities near the wind development, community officials and representatives of various interests, including economic development, conservation and environmental groups. Public involvement is discussed in more detail in Chapters 3 and 4.

Some permitting authorities either require or develop mitigation plans and monitoring programs for dealing with potential environmental impacts. Plans may include grading, erosion control or avian injury and mortality study and reduction plans. Various types of mitigation plans are discussed in Chapter 4.

Financing

To secure financing, a wind project developer needs a site with a permit to develop it, a completely defined project, a power purchase agreement, and firm access to a market. The financing entity must have confidence in the performance and reliability of the wind turbine being chosen for the project. There may be several equity holders in a project who together usually supply 10 to 50% of the project's capital costs. The remainder is borrowed from lending institutions, including banks and insurance companies, over a term of about 12 to 20 years.

Wind project developers can lower costs by taking advantage of the Renewable Energy Production Incentive program included in the Energy Policy Act of 1992. As currently enacted, a privately-owned wind facility beginning operation by June 30, 1999 can qualify for a federal tax credit of $0.015 per kilowatt-hour (adjusted annually for inflation). The federal incentive is applicable to the first ten years of the facility's operation. A wind facility owned by a public entity receives the production incentive as a payment of $0.015 per kilowatt-hour (if funds have been appropriated on an annual basis). The Sacramento Municipal Utility District (SMUD) received $216,000 from the federal incentive in 1995, most of the payment for power produced by SMUD's wind facility in Solano County, California (Windpower Monthly, Nov. 1996).

Construction

The amount of time required to construct a wind project will depend on its size and the terrain and climate of the site. A wind project typically can be built and operational within nine to 18 months. Wind facility construction requires heavy equipment, including bulldozers, graders, trenching machines, concrete trucks, flat-bed trucks and large cranes. Construction normally begins with grading and laying out the access roads and the service roads that run to the wind turbines. After completing the roads, the concrete foundations for the turbine towers and ancillary structures are excavated and poured. Foundation work is followed by digging the trenches for the underground electrical cables, laying the electrical and communication cables, and building the overhead collection system and substation. Next activities include assembling and erecting the wind turbine towers, mounting the nacelles on top of the towers, and attaching the rotors. (See Figure 7.) Once the wind turbines are installed, the electrical connections between the towers and the power collection system are made, and the system is tested.

Figure 7. A large crane is used to raise a rotor into position. Photo courtesy of AWEA.

The construction stage is the point at which some agencies initiate monitoring programs to ensure that project construction and subsequent operation complies with any permit conditions; particularly conditions related to development near sensitive environmental or other resources. Monitoring programs are further discussed in Chapter 3.

Operation

A wind facility is almost completely automated, requiring few on-site personnel. The developer may operate the wind facility directly or by contract with an operation and maintenance company. Under normal conditions, wind turbines will operate automatically. Each wind turbine is equipped with a computer for controlling critical functions, monitoring wind conditions, and reporting information to the control facility. Operators in the control facility monitor the activity of each wind turbine and diagnose the cause of any failure. If the operators are unable to restart the wind turbine directly from the control facility, a crew of specially-trained mechanics ("windsmiths") are dispatched to perform repairs. Control facility operators also monitor the power output from each wind turbine and from the wind facility as a whole.

Repowering/Decommissioning

Repowering of a wind facility entails the removal of individual turbines which are then replaced with new equipment. If a wind project cannot maintain low operating costs but wind turbine technology continues to improve, the economics may support repowering of the site with newer technology. This may allow a site to continue producing power for decades. Over time, however, individual turbines or an entire wind power generating facility may be decommissioned.

The decommissioning of a wind facility entails the dismantling and removal of all wind turbines and towers, as well as the underground and overhead collection and transmission system. Typically, the foundations for the towers and other structures are removed to a specified depth below the ground surface. Depending on the permits and terms of the lease, the wind developer may be required to restore vegetation to the site and return the property to its natural state or prior use. Decommissioning is further discussed under *ACTIVE COMPLIANCE MONITORING* in Chapter 3, and is touched upon in Chapter 4 as it relates to specific permitting considerations.

CONCLUSION

The wind industry has gained considerable experience over the past two decades in constructing and operating both individual wind turbines and larger scale wind facilities. During that time there have been substantial resource assessment and technological improvements. Both wind developers and resource protection agencies have gained an opportunity to understand the potential public health, safety and environmental considerations associated with wind development—and to develop, implement, and improve processes that facilitate the permitting of these facilities. Chapter 3 describes the basic steps in permitting and offers guidelines for structuring a fair, timely, and effective permitting process. Chapter 4 discusses specific permitting considerations and identifies strategies to address issues associated with wind development.

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